Wave Boundary Layer Processes Over an Irregular Bottom

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LONG-TERM GOALS

The broad long-term goal of this research is to extend understanding of wave processes over a very rough boundary, specifically that presented by a coral reef. From this understanding we aim to develop models that account for the effects of roughness on wave dissipation, sediment transport and biophysical interactions.

OBJECTIVES

The objective of this project is to relate measurements of the roughness field to observations of the wave flow at various scales, with the goal of developing a relation between roughness and wave energy dissipation and shear stress. The specific objectives include three elements: 1) observations of the small-scale turbulent processes over a wave orbital amplitude; 2) a broad scale characterization of the wave field and its response to roughness; 3) high-resolution spatial surveys of the roughness over the study region. These observations will be further extended using a numerical model of the wave field in the nearshore region. Concurrent observations of sediment load and optical properties will explore the connection between shear stress and sediment suspension and transport over the complex reef topology.

APPROACH

An array of wave gauges will be deployed on a coral reef on the south shore of Oahu beginning in spring of 2004 with the aim of characterizing the variations in wave energy over a large area (figure 1). At the same time the Rough Boundary Profiler (RBP) will be deployed to characterize the boundary flow at smaller scales, over a wave orbital amplitude. The array will be connected to shore via a powered fiber optic cable allowing real-time data access and long-term deployments. The instrument array also includes a package that will monitor sediment transport in sandy areas on the reef.

The RBP obtains a spatial view of the near-bed flow in a phase-averaged sense using a downward-looking ADCP with high resolution sampling capabilities. Each component of the velocity field is sampled separately and the 2D flow field is reconstructed as a function of wave phase.

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In parallel to the wave dissipation and boundary layer observations we will undertake high-resolution roughness surveys over the observational domain. This data will provide important information on small scales of reef roughness necessary for nearshore wave modeling. We expect to attain an along-track resolution on the order of 20 cm with a vertical resolution of 1-3 cm. Measurement over a large grid with intertrack spacings of 25 m will give a broad view of roughness variations. These observations, combined with the measurements of wave dissipation and shear stress will enable analysis of the relation between roughness spectra and wave boundary layer turbulence.

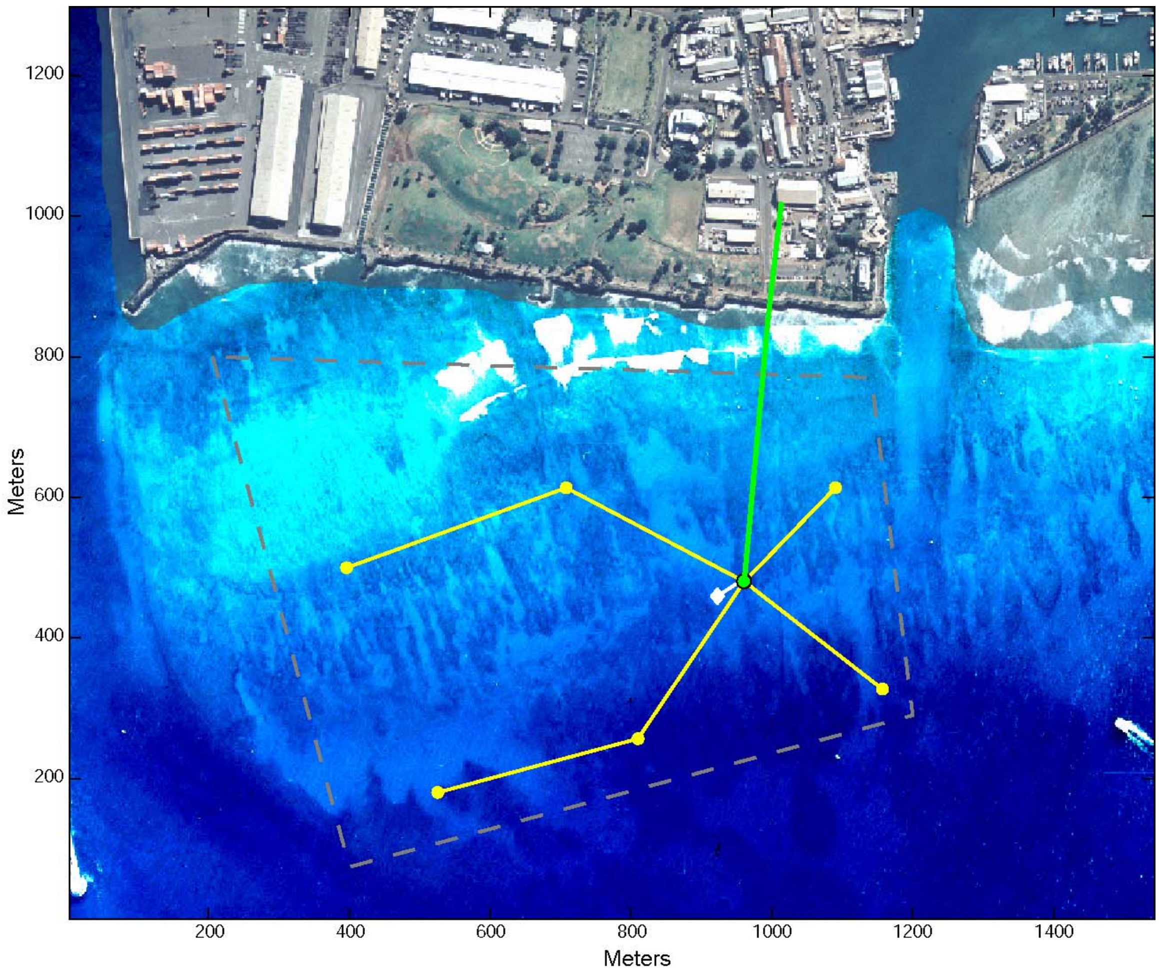

Figure 1: Cabled array layout. Aerial view of Kakaako Waterfront Park and offshore reef region. Instrument array configuration is shown, including the profiling platform and central node (green circle), sediment transport array (white diamond) and shore cable connection (green line). The limits of the roughness survey are shown by the dotted gray line.

WORK COMPLETED

The first five months of the project has been devoted to planning, design of the observational instrument array and cable system and preliminary field measurements. The latter have included wave gauge deployments aimed at characterizing the large scale variations in the wave field, as well as *in situ* sand depth surveys to examine variability.

A boat-based echosounder and ADCP survey system is under development. Preliminary roughness surveys will be carried out in winter of 2003/2004. We have conducted a series of *in situ* roughness surveys for 'ground-truthing' the boat-based surveys. In the process, we have developed various techniques for diver-based roughness measurements that will allow more efficient sampling.

Data analysis from deployments of a pilot version of the RBP is being carried out by Marion Bandet, an ocean engineering PhD student funded by this project. A new, more complete data set has also been collected from a deployment in Kaneohe Bay in August, 2003 using high resolution (pulse coherent) ADCP sampling modes.

RESULTS

Data analysis from preliminary RBP deployments indicates that the phase-averaged approach is in good agreement with instantaneous measurements. The analysis further shows that the method is able to capture large scale flow features associated with roughness (figure 2).

In situ sand depth surveys indicate sand levels vary as much as 10-20 cm over short periods indicating that sediment transport is significant even at 10 m depth.

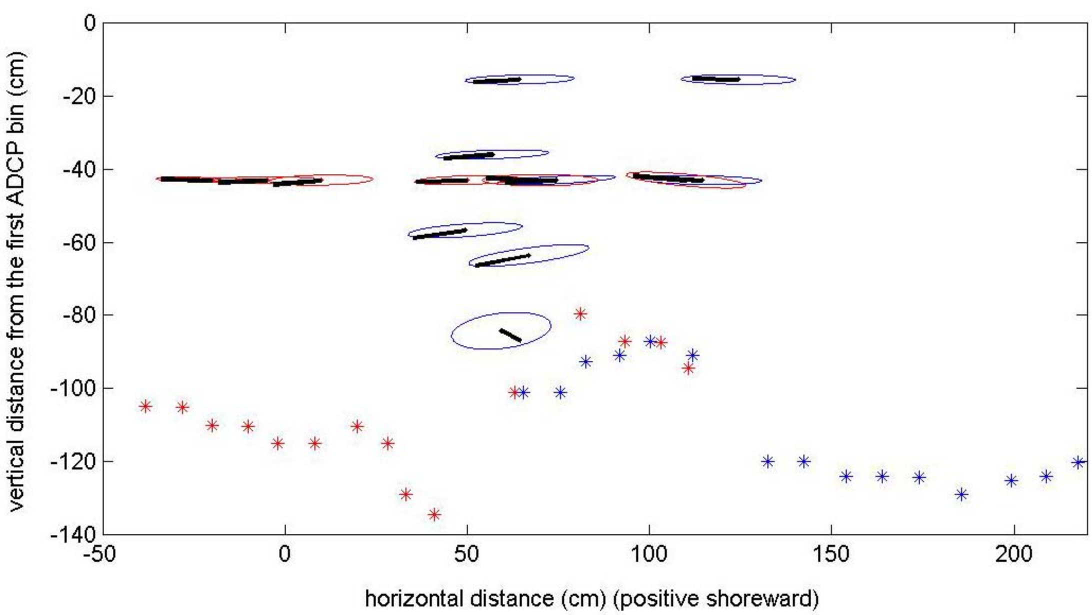

Figure 1: Phase-averaged velocity field from preliminary RBP deployment (10 m depth). Blue ellipses indicate wave motion measured using phase-averaged ADCP measurements (aspect ratio for ellipses is exaggerated by 20:1). Red ellipses show velocities from phase-averaged ADV data in good agreement with the ADCP data. Bottom structure, shown by red/blue stars (ADCP bottom range from two separate beams), is dominated by a large coral head in the center of the domain. Solid lines in each ellipse represent flow velocities in the wave trough. Velocities are consistent with flow veering around the coral head. Phase lag at the lowest location is evidence of flow separation in the lee of the coral head.

IMPACT/APPLICATIONS

Our observations of the interactions between waves and the rough boundary over a coral reef will lead to more accurate parameterizations of bed shear stress and wave dissipation as a function of roughness for use in wave and sediment transport modeling over irregular boundaries. Nearshore numerical wave models typically use roughness parameterizations based on uniform roughness, which is only loosely related to the actual roughness over a reef. Illuminating the turbulent processes over a rough boundary will have further benefits to understanding oscillating flows over irregular boundaries in general with applications to flow around support structures, buried objects and pipelines and cables, as well as to larger scale oceanographic boundary flows.

An additional benefit of the work underway will be the establishment of a cabled observatory in a reef environment. This will enable real-time access to data and facilitate deployment of instruments that would otherwise be limited to short-term deployments.

TRANSITIONS

A field observational project, funded by NSF, will begin in 2004 making use of the cabled observatory to examine the wave-induced flow and enhanced dispersion within a sandy bed (PIs: Frank Sansone, Geno Pawlak, Mark Merrifield and Ian Webster). This project will also require characterization of the bedforms in the study region.

RELATED PROJECTS

We have been working closely with researchers from UH (Marlin Atkinson, Jim Falter) and Stanford University (Stephen Monismith, Jeff Koseff). Their studies, funded by NSF, aim to relate wave boundary layer processes to nutrient uptake by coral communities. They have constructed an oscillating flume to examine the chemical aspects of the flow and have carried out field observations exploring the dissipation of waves over a reef flat in Kaneohe Bay. We participated in the most recent set of observations in August, 2004 where the pilot version of the RBP was deployed. We are collaborating with the Stanford group on data analysis.

The UH Seagrant program is also providing funding to support an ocean engineering master's student (Vasco Nunes) in 2003 through two development grants. These grants are supporting further deployments of the RBP along with development of the field roughness survey capabilities.